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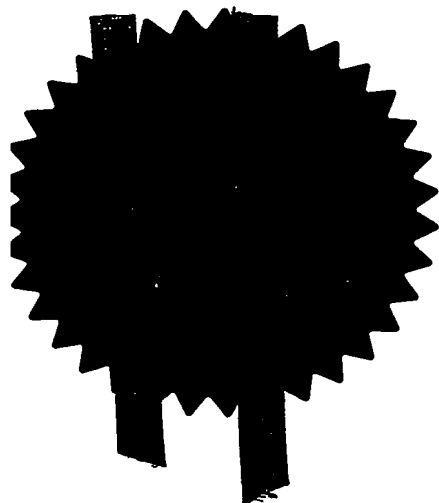
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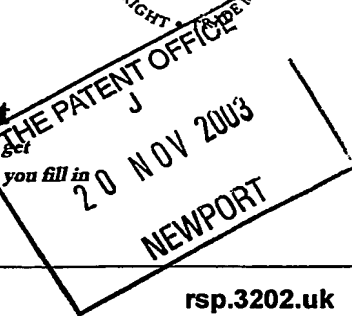




1/77

Request for grant of a patent

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The Patent Office

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1. Your reference

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2. Patent application number

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0327021.2

7/11/03 E953754-1 D10002
1/7700 0.00-0327021.2

3. Full name, address and postcode of the or of each applicant (underline all surnames)

Red Spider Technology Limited
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United Kingdom

Patents ADP number (if you know it)

If the applicant is a corporate body, give the country/state of its incorporation

8751794001

20 NOV 2003

4. Title of the invention

Improved valve

5. Name of your agent (if you have one)

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

Kennedys Patent Agency Limited
Floor 5, Queens House
29 St Vincent Place
Glasgow
G1 2DT

Patents ADP number (if you know it)

0805 824 0002

6. Priority: Complete this section if you are declaring priority from one or more earlier patent applications, filed in the last 12 months.

Country

Priority application number
(if you know it)

Date of filing
(day / month / year)

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute (see note f)

Number of earlier UK application

Date of filing
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8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request?

Answer YES if:

- a) any applicant named in part 3 is not an inventor, or
- b) there is an inventor who is not named as an applicant, or
- c) any named applicant is a corporate body.

YES

Otherwise answer NO (See note d)

Patents Form 1/77

9. Accompanying documents: A patent application must include a description of the invention. Not counting duplicates, please enter the number of pages of each item accompanying this form:

Continuation sheets of this form

Description

17

Claim(s)

Abstract

Drawing(s)

7

10. If you are also filing any of the following, state how many against each item.

Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent (Patents Form 7/77)

Request for a preliminary examination and search (Patents Form 9/77)

Request for a substantive examination (Patents Form 10/77)

Any other documents (please specify)

11. I/We request the grant of a patent on the basis of this application.

Signature(s)

Kennedys
KENNEDYS PATENT AGENCY LTD Date 19.11.03

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom

Arlene Campbell

Tel: 0141 226 6826

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1 Improved Valve

2

3 The present invention relates to valves typically used on
4 downhole tools in oil and gas wells and in particular,
5 though not exclusively, to a water injection valve.

6

7 In secondary recovery of oil and gas wells it is possible
8 to use the technique of water flooding for enhanced oil
9 recovery. This technique relies on injecting water into
10 the reservoir and is normally undertaken using one or
11 more water injection wells. Such valves are typically
12 made up to a wireline lock or retrievable bridge plug and
13 run to depth, usually in the packer tail pipe. A
14 suitable valve design comprises a body having one or more
15 ports which include seat(s) against which a poppet or
16 other closing surface of the valve can rest. The poppet
17 is biased towards the seat(s) to block off the ports and
18 hold the valve in a closed position. Water passed down
19 the tubing string of a well bore will arrive at the
20 poppet, seated in a closed position. Water pressure will
21 work against the loading of the spring and force the
22 poppet away from the seat. This exposes the ports and
23 thus water is ejected from the body of the tool to the

1 annulus between the tool and the well bore for injecting
2 into a formation.

3

4 Such valves have a number of disadvantages. Typically
5 these valves have a spring which applies a load to the
6 poppet to keep the valve closed. Thus when water flows
7 an initial pressure will open the valve but there is a
8 tendency for the valve to close again as the pressure
9 drops when the fluid is flowing through the valve.

10

11 Some water injection valves are designed as high lift
12 valves. Such valves are designed so that the poppet
13 moves easily to the full open position with the minimum
14 water injection flow rate. Unfortunately such a high
15 lift design results in a low load spring design producing
16 low resultant closing forces on the poppet mechanism.
17 This can lead to problems with debris ingress between the
18 poppet and seat preventing a seal.

19

20 A further disadvantage of these valves is in the
21 arrangement of the ports through which the water flows
22 when the valve is open. By the nature of the design,
23 these ports are typically small in diameter and as such
24 they increase the pressure drop through the valve, cause
25 erosional problems through the valve and increase the
26 potential debris build up at these ports.

27

28 It is an object of at least one embodiment of the present
29 invention to provide a valve which overcomes at least
30 some of the disadvantages of prior art valves.

31

1 It is a further object of at least one embodiment of the
2 present invention to provide a water injection valve
3 which is a high lift valve.

4
5 A yet further object of at least one embodiment of the
6 present invention is to provide a water injection valve
7 having a high bypass flow area.

8
9 According to a first aspect of the present invention
10 there is provided a valve for use in a downhole tool, the
11 valve comprising first and second sealing surfaces
12 moveable with respect to each other to create a passage
13 therebetween, the first surface being moved by biasing
14 means toward the second surface and characterised in that
15 a load adjuster is located between the biasing means and
16 the first surface to vary the load applied by the first
17 surface upon the second surface.

18
19 In a typical valve, as the first surface approaches the
20 second surface to move the valve to the closed position,
21 the load from the biasing means is at its lowest and the
22 potential for debris build-up between the surfaces is at
23 its highest. By incorporating a load adjuster, the load
24 can be increased as the valve is closed, to pull the
25 valve to the fully closed position. This increases the
26 surface to surface contact load and resulting sealing
27 performance of the valve.

28
29 Preferably the biasing means is a spring. More
30 preferably the biasing means is arranged on a central
31 axis of the valve.

32

1 Preferably the load adjuster comprises a sprung collet.
2 The sprung collet may comprise an engaging portion having
3 sprung cantilevers extending therefrom. The engaging
4 portion may be considered as a dog. Preferably the
5 collet is arranged in parallel to the central axis.

6
7 Preferably the load adjuster further includes at least
8 one roller. Preferably at least one roller is mounted on
9 the engaging portion or dog.

10
11 Preferably the roller is located against a running
12 surface of the valve wherein the running surface is
13 substantially parallel to the central axis. More
14 preferably the running surface comprises three sloping
15 sections, a first sloping section being at a first angle
16 to the running surface, a third sloping surface being at
17 a second angle to the running surface and an apex of the
18 first sloping surface being connected to the base of the
19 third surface to provide the second sloping surface.

20
21 In an embodiment of the present invention the first and
22 third sloping surfaces are angled at approximately ninety
23 degrees to the running surface. In an alternative
24 embodiment of the present invention the first and third
25 sloping surfaces are at a steep angle to the running
26 surface.

27
28 Preferably the valve comprises a first substantially
29 tubular body having a second substantially tubular body
30 located therein. Preferably also the second tubular body
31 includes the first sealing surface while the first
32 tubular body includes the second sealing surface.

33

1 Preferably the first sealing surface is an outer surface
2 of a poppet located at an end of the second tubular body.
3 Preferably the second sealing surface is a seat located
4 circumferentially on an inner surface of the first
5 tubular body.

6
7 Preferably biasing means is provided in the second
8 tubular body. Advantageously the biasing means is a
9 spring located centrally within a bore of the second
10 tubular body.

11
12 Preferably a first end of the spring locates at a base of
13 the second tubular body while a first end of the spring
14 locates at a base of the poppet. Preferably the poppet
15 is arranged to slide on an outer surface of the second
16 tubular body.

17
18 More preferably the load adjuster is arranged on an inner
19 surface of the poppet and the running surface is arranged
20 on an outer surface of the second tubular body. In this
21 way biasing of the spring causes movement of the load
22 adjuster along the outer surface of the second tubular
23 body. In a preferred embodiment the sprung collet
24 ensures that the roller is located against a sloping
25 surface of the running surface when the tool is
26 assembled.

27
28 Advantageously the first tubular body includes a
29 plurality of ports located thereon. Preferably the ports
30 are arranged circumferentially on the first tubular body.
31 More preferably the cross-sectional area of the ports is
32 greater than half the total surface area of the first
33 tubular body. In a preferred embodiment there are two

1 rectangular ports located on the first tubular body. The
2 ports are arranged such that they take up a substantial
3 portion of the tubular body to provide for maximum flow
4 through of fluid when the valve is open. In the
5 preferred embodiment portions of the tubular body between
6 the ports provide longitudinally arranged rails.

7
8 Preferably the outer surface of the poppet engages with
9 the rails to maintain linear movement of the poppet
10 within the first tubular body.

11
12 Preferably the valve is an injection valve. The valve may
13 be a water or gas injection valve. Alternatively the
14 valve is a check valve as would be used in a downhole
15 safety device.

16
17 While the terms 'up', 'down', 'top' and 'bottom' are used
18 within the specification, they should be considered as no
19 more than relative, as the valve of the present invention
20 may be used in any orientation.

21
22 An embodiment of the invention will now be described by
23 way of example only with reference to the accompanying
24 figures in which:

25
26 Figure 1 is a part cut-away cross-sectional view
27 through a valve according to an embodiment of the
28 present invention;

29
30 Figures 2 (a) and (b) are schematic illustrations of
31 the position of the poppet seat and poppet when the
32 valve of Figure 1 is moved to the closed position;

33

Figure 3 is a cross-sectional view of the valve of Figure 1 divided in two parts wherein the left hand side of the figure illustrates the valve in the open configuration and the right hand side illustrates the valve in the closed configuration;

Figure 4 is a plot of valve closing characteristics comparing the spring load on a traditional injection valve against that of an injection valve according to the present invention; and

Figures 5 illustrate a schematic view of the arrangement of the flow housing on the valve of Figure 1 wherein Figures 5 (a), (b) are rotated by ninety degrees with respect to Figures (c), (d).

Referring initially to Figure 1 of the drawings there is illustrated a valve, generally indicated by reference numeral 10, according to a first embodiment of the present invention. Figure 1(a) is a top section of the valve 10, while Figure 1(b) is a lower section of the valve 10. To those skilled in the art, valve 10 is recognisable as a water injection valve but could equally be adapted to a check valve or other arrangement as would be found on a downhole tool for controlling fluid flow.

Valve 10 comprises a top sub 12 including a box section 14 for connecting the valve 10 to an anchoring device i.e. a lock or bridge plug. Typically the valve is made up to an wireline lock or retrievable bridge plug and run to depth, usually in the packer tail pipe. Threaded to the top sub 12 is a flow housing 18. The design of flow housing 18 is advantageous to the operation of the

1 injection valve and will be described hereinafter with
2 reference to Figures 5. The housing 18 is primarily a
3 tubular body providing an outer surface 20 to the valve
4 10. At a lower end 22 of the housing 18 is attached a
5 bottom sub or end cap 24. End cap 24 is threaded to the
6 housing 18 and prevented from detachment by means of set
7 screws 26. There is also located an adjustment nut 28 and
8 an adjacent lock nut 30 so that the relative positioning
9 between end cap 24 and the housing 18 can be set.

10

11 End cap 24 includes a bore 32 into which is located a
12 inner tube 34. Inner tube 34 provides a tubular body
13 having an inner cylindrical surface 36 and an outer
14 surface 38. Mounted within the inner cylindrical surface
15 and abutting a base 40 of the bore 32 is a spring 42.
16 Spring 42 extends beyond the upper end 46 of the inner
17 tube 34.

18

19 From the end 46, the outer surface 38 provides a
20 substantially longitudinal portion 48, running in
21 parallel to the spring 42 which is aligned on a central
22 axis 50 of the valve 10. Portion 48 meets a face 52
23 which rises outwardly from the surface 38 at an angle of
24 approximately seventy-five degrees. This provides an
25 acute ramp on the outer surface 38. Thereafter the outer
26 surface provides a gentle ramp 56 toward a second face 54
27 which provides a second acute face as that of the face
28 52. Between each face 52, 54 the outer surface 38 the
29 gentle ramp 56 extends from the apex 60 of the face 52 to
30 the base 62 of the face 54. This ramp 56 is directed
31 toward the central axis 50 as it travels toward the end
32 cap 24.

33

1 Located below the face 54 are the end portions of a first
2 collet spring 66 and a poppet skirt 68. The collet spring
3 66 and the poppet skirt 68 are threaded together and
4 locked by set screws 64. The collet spring 66 and the
5 poppet skirt 68 can slide on the outer surface 38 of the
6 inner tube 34.

7
8 Collet spring 66 extends toward the upper end 70 of the
9 valve 10 providing a cantilevered release spring
10 terminating at a dog 72. Dog 72 is a typical dog
11 providing inner 74 and outer 76 raised portions. Although
12 only one dog 72 is illustrated, it will be appreciated
13 that any number can be arranged around the inner tube 34
14 Dog 72 is connected to a further collet spring 78 whose
15 end 80 extends toward the upper end 70 of the valve 10.
16 The collection of collet spring 78, dog 72 and collet
17 spring 66 'fingers' provide a collet generally indicated
18 by reference numeral 100.

19
20 Typically, the collet 100 is formed by turning a profile
21 onto a cylinder and then milling parallel slots through
22 the cylinder axially within its length. The amount of
23 parallel slots arranged around the circumference equals
24 the number of fingers (collet spring 78, dog 72 and
25 collet spring 66). The fingers act like a beam supported
26 at each end. End 80 of collet 100 is cylindrical and
27 supported within a corresponding cylindrical inner
28 surface 82 of a poppet 84.

29
30 The poppet skirt 68 is threaded and held by set screws 86
31 to a recess 88 on an outer surface 90 of the poppet 84.
32 Located above the collet spring 78 on the poppet 84 is a
33 spring washer 92. Spring washer 92 includes an inner lip

1 94 arranged to face the end cap 24 and retain a top end
2 96 of the spring 42.

3

4 Mounted upon the dog 72 is a wheel 102 arranged so that
5 it can ride upon the outer surface 38 of the inner tube
6 34. Indeed the wheel 102 may locate on the face 52, run
7 along the ramp 56 towards face 54 as described
8 hereinafter with reference to the accompanying figures.

9 An end 69 of the skirt 68 meets an inner surface 71 of
10 the flow housing 18. An end 69 Spring 42 is thus
11 contained between a base 40 of the end cap 24 and the lip
12 94 of the spring washer 92 and its movement is controlled
13 by the movement of the collet 100 in relation to the
14 outer surface 38 of the inner tube 34.

15

16 The poppet 84 provides a rounded nose cone 104 which
17 locates in a bore 106 on the top sub 12. Poppet 84
18 further provides a frusto-conical surface 108 which
19 includes a ledge 110 which provides a sealing surface 111
20 to seal against a poppet seat 112 located on the flow
21 housing 18. Poppet seat 112 provides a further sealing
22 surface 113 which when it meets the surface 112 seals the
23 bore 106 to prevent fluid flow which enters the bore 106
24 from exiting the valve 10. This configuration can
25 therefore be considered as a closed configuration of the
26 valve 10. Appropriate O-rings 114a and 114b are located
27 between the poppet seat 112 and the inner surface 116 of
28 the flow housing 18, and between the top sub 12 and the
29 flow housing 18, respectively. This prevents the ingress
30 of fluid through the valve 10.

31

32 The ledge 110 and thus the poppet 84 is held against the
33 poppet seat 112 initially by the spring 42 and further by

1 the collet 100 when the dog 72 is located at the face 52
2 and the wheel 102 abuts the face 52.
3

4 This closed position is further illustrated with the aid
5 of Figures 2. In Figure 2(a) the wheel 102 is located at
6 the apex 60 of the face 52. At this position the poppet
7 seat 112 and the poppet 84 are close to touching. This
8 is the location that a typical water injection valve of
9 the prior art would find its spring load at its lowest
10 and the potential for debris problems are at their
11 highest. At this position the collet 100 and in
12 particular the collet springs 66, 78 take over from the
13 spring 42 and drive the poppet 84 to the fully seated
14 position against the poppet seat 112. As this occurs the
15 wheel 102 runs down the acute face 52 and locates there
16 against. The poppet seat 112 is now located within the
17 ledge 110 of the poppet 84 and the surfaces 111,113 seal
18 together.
19

20 In this position the collet 100 preloads the poppet 84
21 against the poppet seat 112. Thus the collet 100 has
22 pulled the valve to the fully closed position. This
23 increases poppet 84 to seat 112 contact load and enhances
24 the resultant sealing performance of the valve.
25

26 This closed position is shown on the right hand side of
27 Figure 3 wherein the poppet 84 is seated on the poppet
28 seat 112 and there is no flow through the valve. In
29 order to initiate flow through the valve, water or other
30 fluid is passed through the bore 106. Water causes a
31 pressure on the nose 104 of the poppet 84 and pushes it
32 towards the end cap 24.
33

1 Opening of the valve occurs as poppet 84 moves downwards
2 as shown on the left hand side of Figure 3. As it moves
3 downwards a flow passage 120 is uncovered through the
4 housing 18. On depression of the poppet 84, the wheel
5 102 is caused to ride up the face 52. The seal between
6 the surfaces 111,113 is broken. Due to the close fit
7 between the ledge 110 and the seat 112, the load due to
8 the, now leaking, pressure will be sufficient to allow
9 the wheel 102 to reach the apex 60. Once over the apex 60
10 the wheel runs rapidly down the ramp 56 towards the face
11 54. An end 69 of the poppet skirt 68 meets an inner
12 surface 71 of the flow housing 18. Once the dog 72 has
13 been pushed out of the groove provided by face 52 on
14 valve opening, the drag friction from the collet 100 has
15 been minimised so this does not detract from the spring
16 42 return load.

17

18 Thus when the valve is opened, the valve operates as a
19 high lift valve. This means the poppet 84 moves easily to
20 the full open position with minimal water injection flow
21 rate. Use of the high lift design minimises potential
22 for debris build up above the valve at the location of
23 the seat 112 in the top sub 12.

24

25 Reference is now made to Figure 4 of the drawings which
26 is a plot of valve position 122 between the open and
27 closed configuration against spring load on the poppet
28 84. Two graphs are provided. The first 126 shows a
29 typical injection valve load characteristic for prior art
30 injection valves. In this configuration it is seen that
31 the load follows a straight line from a high spring load
32 125 when the valve is fully open, down to a lower value
33 123 when the valve is closed. This is a linear

1 relationship. Valve 128 illustrates the valve load
2 characteristics of a valve according to the present
3 invention. The initial loading at valve open is similar
4 to that of the traditional valve 126. It follows the
5 same linear downward path until just before the valve is
6 closed at position 130. As the valve is closed an
7 additional load is generated by the collet springs 66, 78
8 and as a result the graph rises sharply to a value 127
9 which may be considerably larger than the value of the
10 spring load of the traditional valve in the closed
11 configuration.

12
13 Returning to Figure 3, there is illustrated a poppet
14 skirt 68. Poppet skirt 68 is threaded to the recess 88
15 on the poppet 84. The skirt 68 provides a streamlined
16 profile running back to the threads 64 which attach it to
17 the collet 100. Such a profile of the nose 104 together
18 with the skirt 68 provides a streamlined flow passage 120
19 to maximise fluid flow through the valve in the open
20 position. This is further enhanced by the design of the
21 flow housing 18 located around the inner tube 34. This
22 is seen with the aid of Figure 5.

23
24 Figures 5 (a) and (b) provide a side view of the housing
25 18, while Figures 5(c) and 5(d) are of the same housing
26 rotated by 90 degrees. Flow housing 18 comprises a
27 tubular body 130 which has a diameter equal to the
28 diameter of the top sub 12 beside the sub 12. Oppositely
29 arranged on the body 130 are two slots or ports 132.
30 Ports 132 are arranged longitudinally and cover a
31 substantial portion of the valve 10, beginning at the top
32 sub 12 and ending near the end cap 24. Ports 132 are
33 substantially rectangular in cross-section having a

1 rounded portion 134 toward the end cap 24. The ports 134
2 may be of any chosen dimensions. The shape in this
3 embodiment is as a consequence of milling through a
4 cylinder formed on a slope. Together the ports 132 remove
5 a substantial portion of the body 130 to provide maximum
6 flow of fluid through the valve 10. Portions of the body
7 30 remaining to either side of the ports 132 provide
8 rails 136 illustrated in Figures 5(c) and 5(d). The
9 rails help guide the poppet 84 through the valve without
10 impeding its path. Thus as can be seen from Figures 5(a)
11 and 5(b), the poppet 84 and poppet skirt 68 are
12 substantially exposed within the body 130.

13

14 This cut-away to flow housing 18 results in the valve 10
15 having a high bypass flow area which minimises the
16 pressure drop and erosion problems through the valve 10.
17 This additionally reduces the debris build up potential.

18

19 Where high injection rates and/or the potential for a
20 highly debris laden environment are anticipated, then the
21 addition of a debris skirt can be made. This skirt will
22 reduce the flow area through the valve however.

23

24 It is also noted that the collet 100 is located within a
25 "dead area" of the valve 10 where fluid flow is not
26 experienced and this minimises the effects to the flow
27 and keeps it away from any debris passing through the
28 valve 10.

29

30 In an alternative embodiment, the areas of the valve 10
31 which are exposed to the injection flow rates such as the
32 nose cone 104 and surfaces of the flow housing 18, may be
33 coated with a tungsten carbide based coating. The

1 coating is directed to areas where the direction of flow
2 changes in particular. The coating is included to help
3 protect the valve sealing surfaces from the effects of
4 erosional flow particularly when large amounts of debris
5 are anticipated. Such coatings are known to those
6 skilled in the art of downhole ball valve technology.

7
8 In an alternative embodiment of the present invention,
9 the poppet seat 112 is made reversible which will help
10 reduce valve redress costs. In a yet further embodiment,
11 the poppet seat is provided as a soft seal. This
12 embodiment is thus particularly suitable for applications
13 where water and gas are injected alternately through the
14 valve and the soft seal improves the gas sealing
15 characteristics of the valve.

16
17 In use, valve 10 is run into a well bore typically made
18 up to a wireline lock or a retrievable bridge plug, and
19 run to depth in the closed configuration. Once in
20 position, fluid to be injected through the valve 10 is
21 introduced to the bore 106 at a suitable pressure. Fluid
22 pressure exerted on the nose 104 of the poppet 84 acts
23 against the spring 42. The poppet 84 is thus moved from
24 sealing engagement with poppet seat 112 in a downwards
25 relative direction. On opening, the wheel 102 of the
26 collet 100 rides up the face 52 of the surface 38 and
27 then runs down the ramp 56 towards face 54. An end 69 of
28 the skirt 68 meets an inner surface 71 of the flow
29 housing 18. The valve is now open. Flow rate through the
30 valve is through bore 106 into flow ports 120 exiting
31 through the ports 132 within the flow housing 18.

32

1 When the valve is to be closed, water pressure is reduced
2 in the bore 106. Load from the spring 42 acts against
3 the poppet 84 to move it back toward the poppet seat 112.
4 Movement is effected relatively easily as the wheel 102
5 of the collet 100 moves up the ramp 56. When the wheel
6 102 reaches the apex 60 of the face 52 the collet springs
7 66, 78 take over from the spring 42 and drive the poppet
8 84 into the seated position against the poppet seat 112.
9 Surfaces 111 and 113 abut to form a seal. In the fully
10 seated position collet 100 preloads the poppet 84 as the
11 wheel 102 is now located against the face 52.

12

13 The principle advantage of the present invention is that
14 it provides a valve for a downhole tool in which the load
15 upon the poppet can be maximised when the valve is closed
16 and the poppet is seated against the poppet seat.

17

18 A further advantage of the present invention is that it
19 provides an injection valve having a high bypass flow
20 area which minimises pressure drop and erosion problems
21 through the valve while also reducing debris build-up
22 potential in the valve.

23

24 A yet further advantage of the present invention is that
25 it provides an injection valve which is a high lift
26 valve. By use of a collet, including a wheel, a poppet
27 moves easily to the full open position with minimal
28 injection flow rate applied.

29

30 It will be appreciated by those skilled in the art that
31 modifications may be made to the invention herein
32 described without departing from the scope thereof. For
33 instance the number of dogs upon the collet may be varied

1 dependent on the adjustment to the load required in the
2 design of the valve. Additionally though a poppet is
3 shown, any suitable arrangement of two sealing surfaces
4 could be used. Yet further the size and number of ports
5 in the flow housing may be changed to vary the flow rate
6 through the valve.

7

CUT AWAY SECTION SHOWING THE INJECTION VALVE
IN THE CLOSED POSITION

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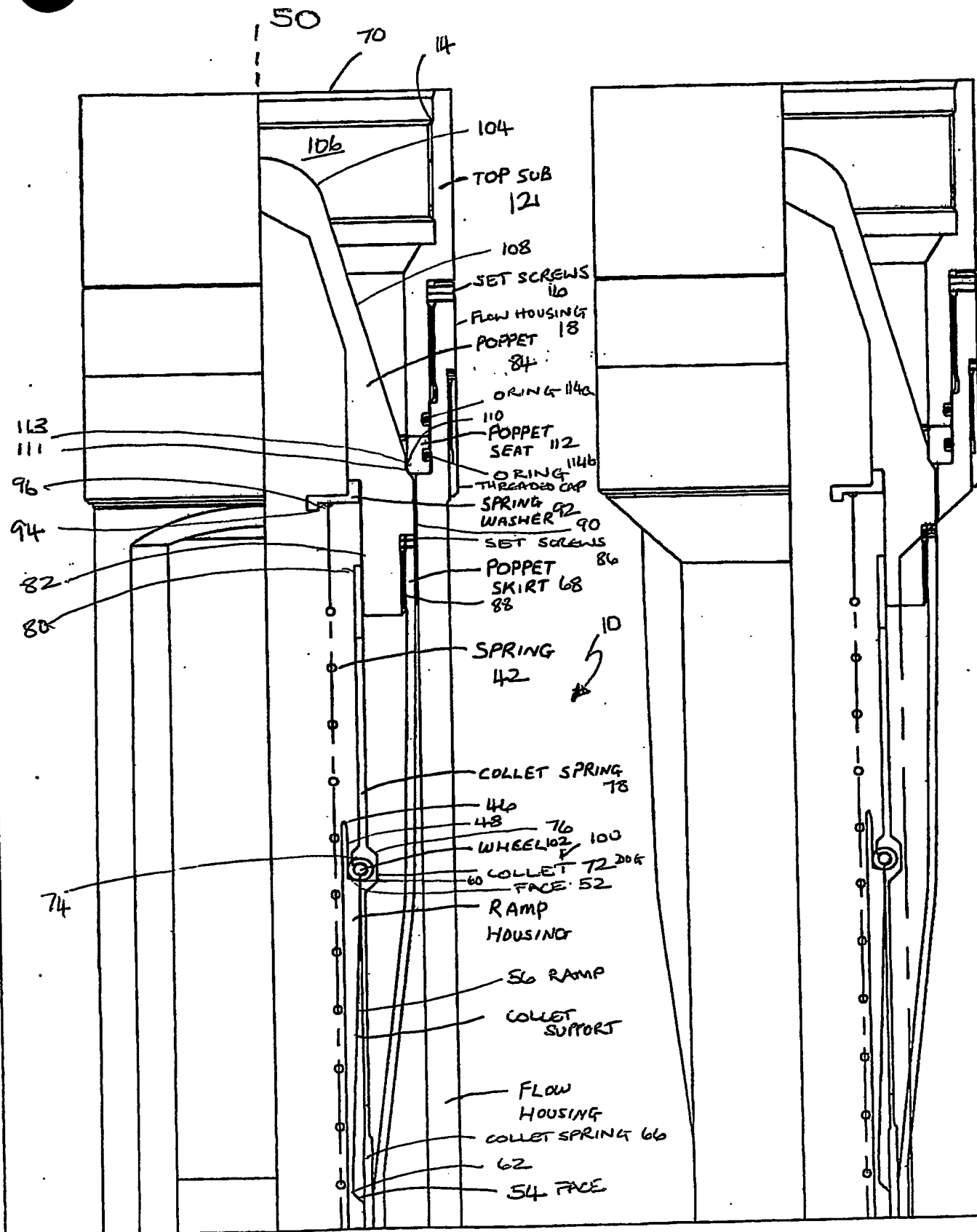


FIGURE 1(a)

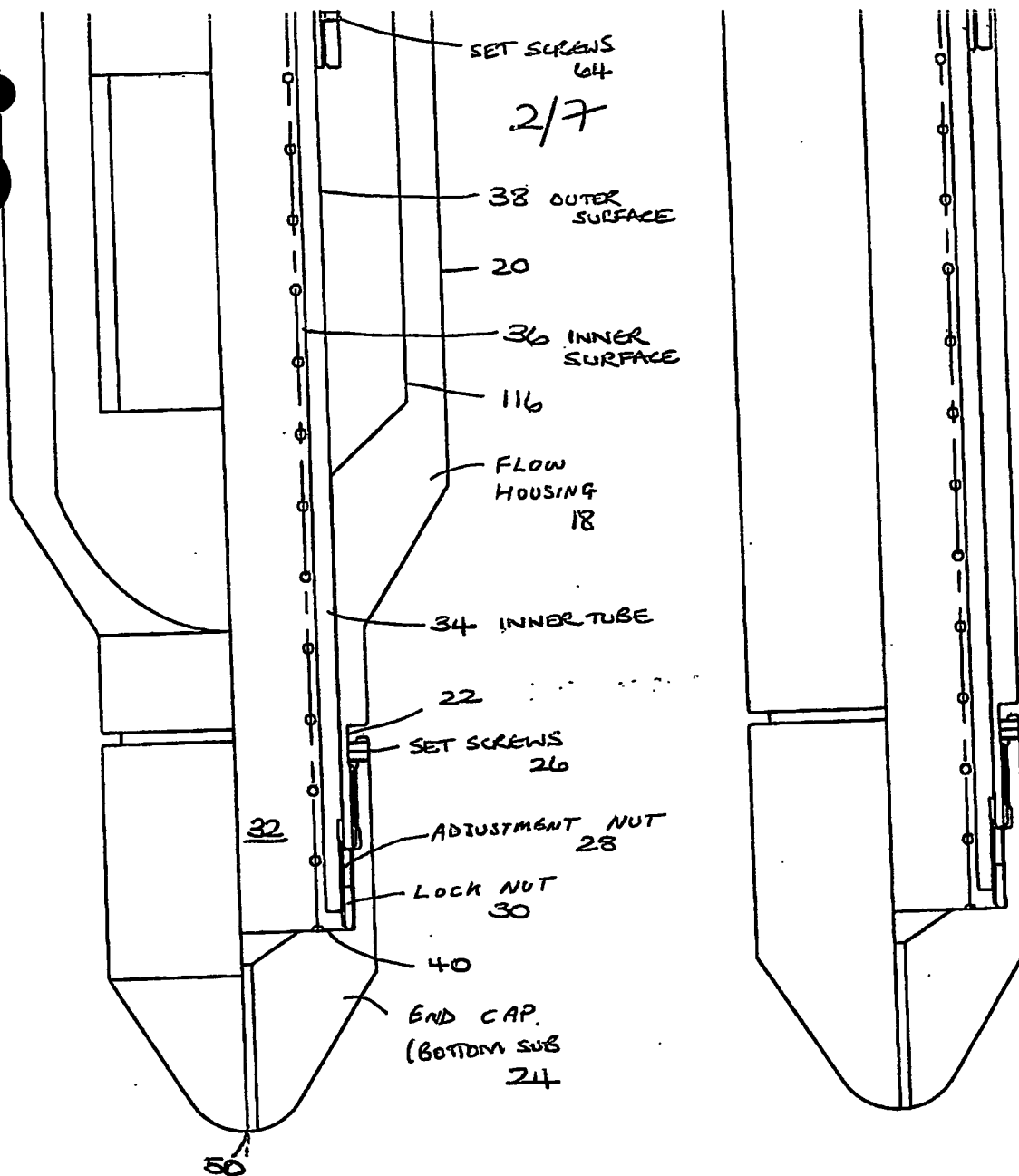


FIGURE 1(b)

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AT THIS POSITION COLLET SPRING TAKES OVER FROM THE
SPRING AND DRIVES THE POPPET TO THE FULLY SEATED
POSITION

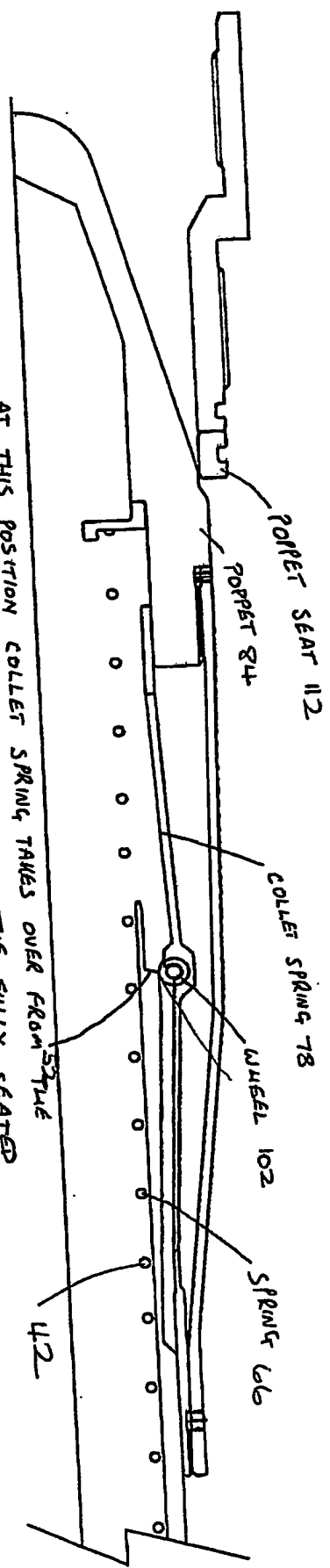


FIGURE 2(a)

VALVE IN FULLY SEATED POSITION. COLLET SEAT PRELOADS
THE POPPET AGAINST THE POPPET SEAT.

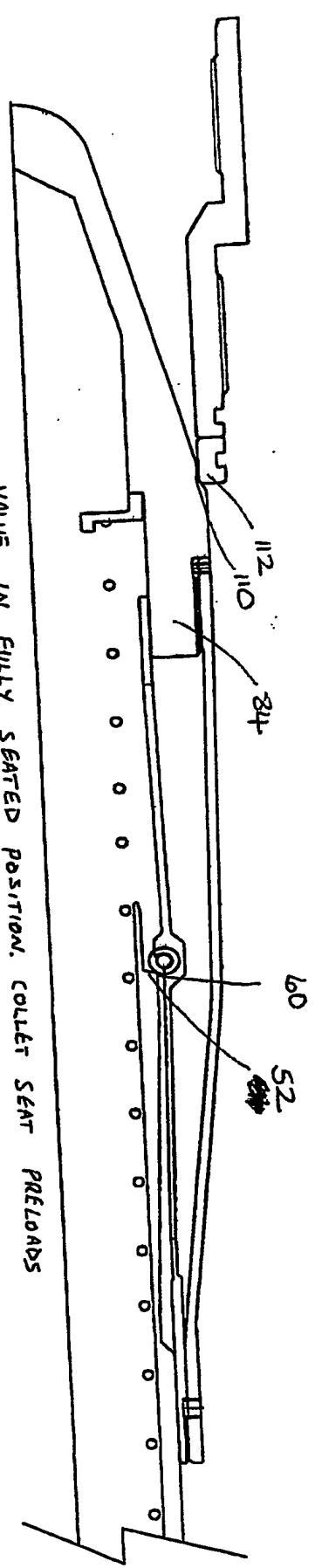


FIGURE 2(b)

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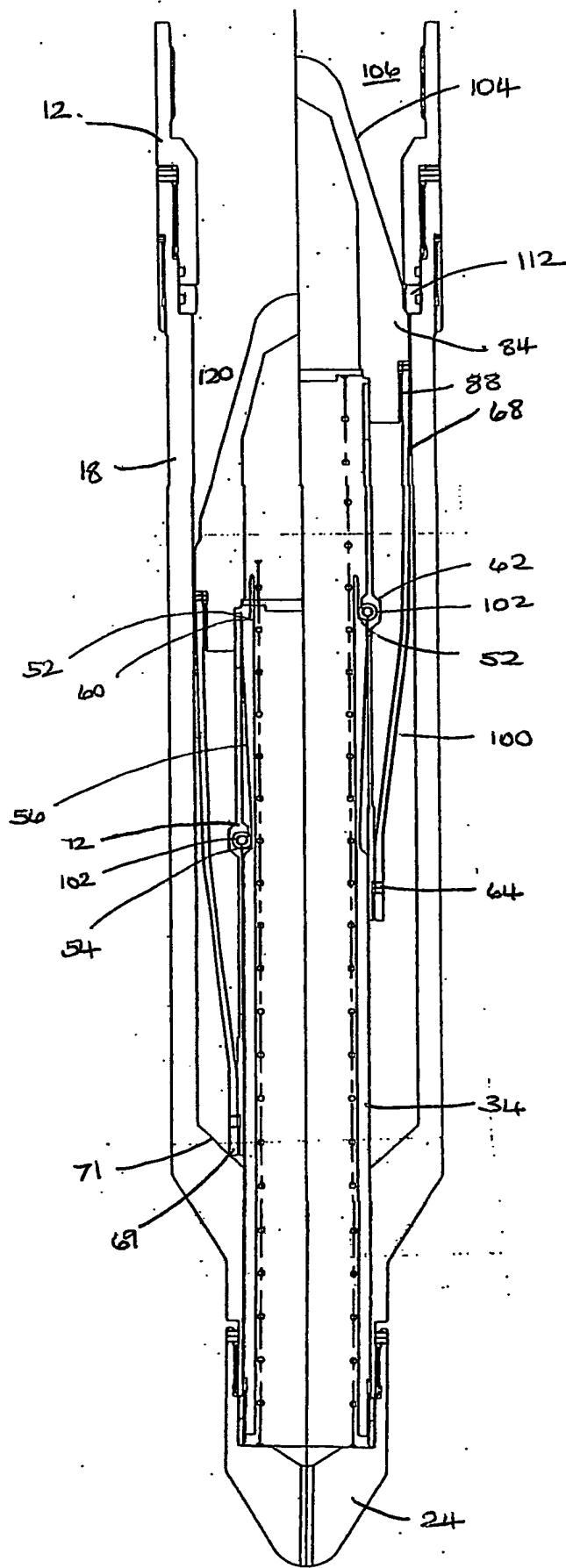


FIGURE 3

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Valve Closing Characteristics

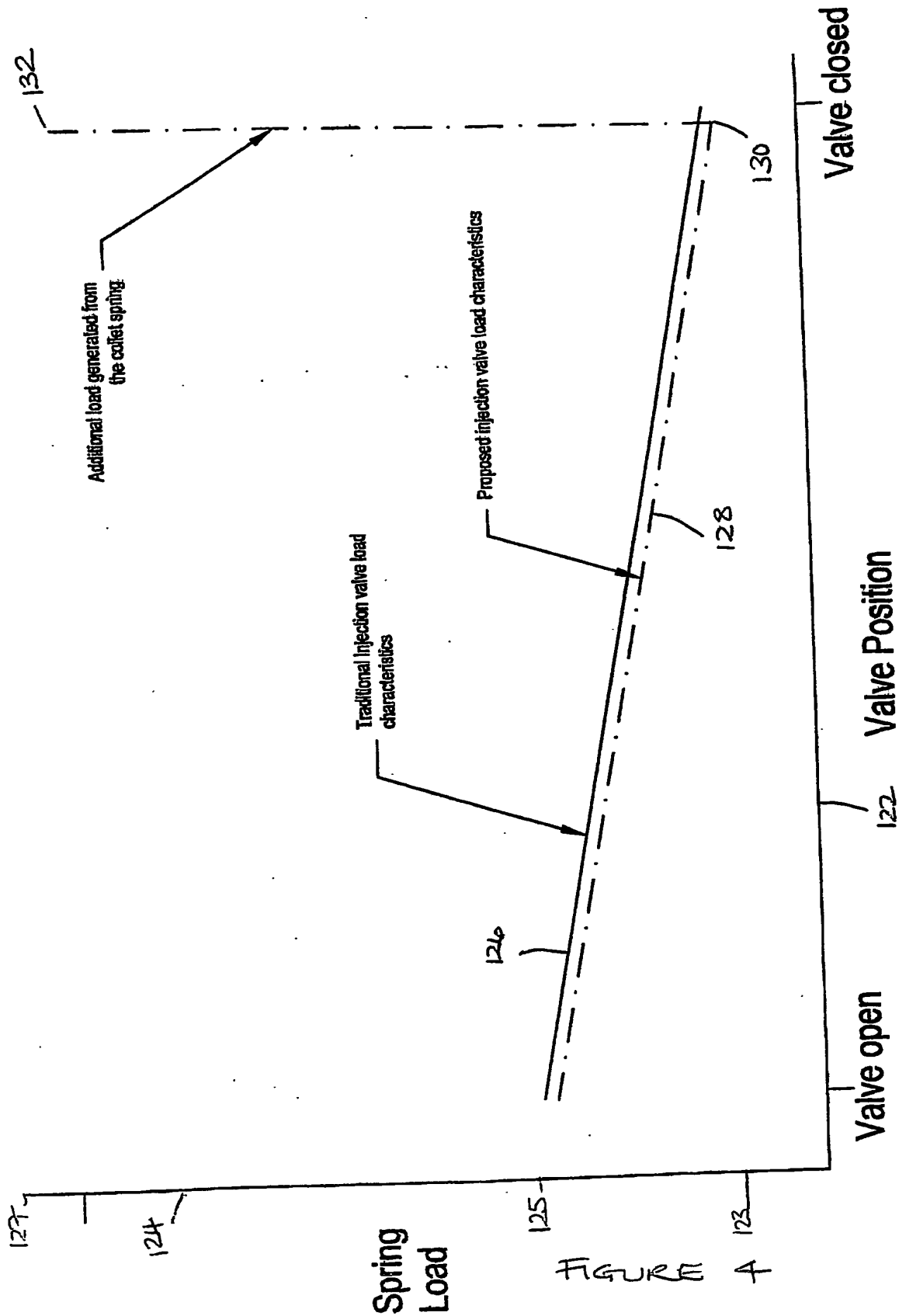
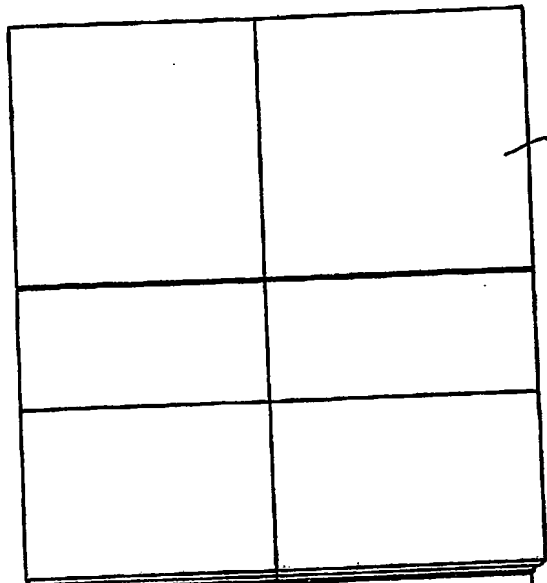


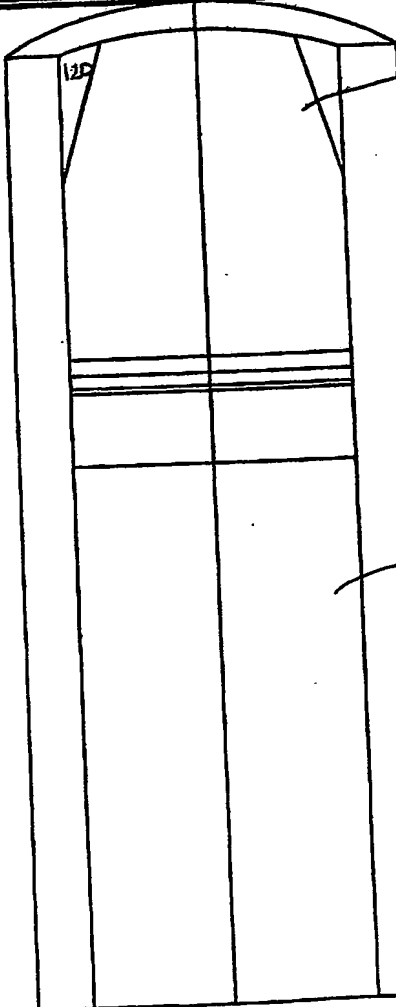
FIGURE 4

INJECTION VALVE SHOWN IN THE OPEN POSITION.
(OUT. SIDE VIEW)

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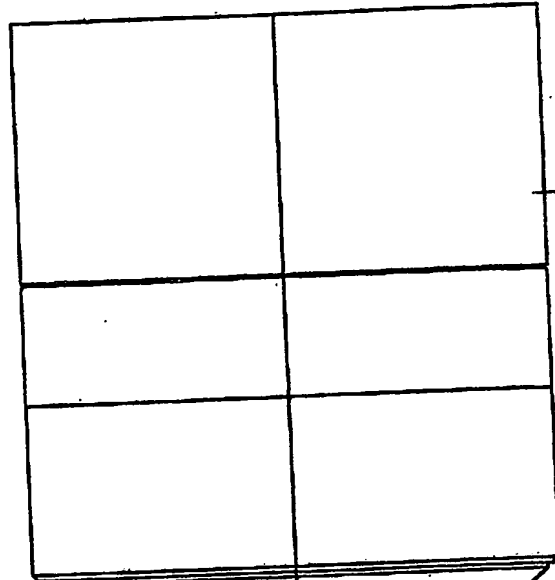
TOP SUB
12



POCKET
84

FLOW HOUSING

POCKET SKIRT
68

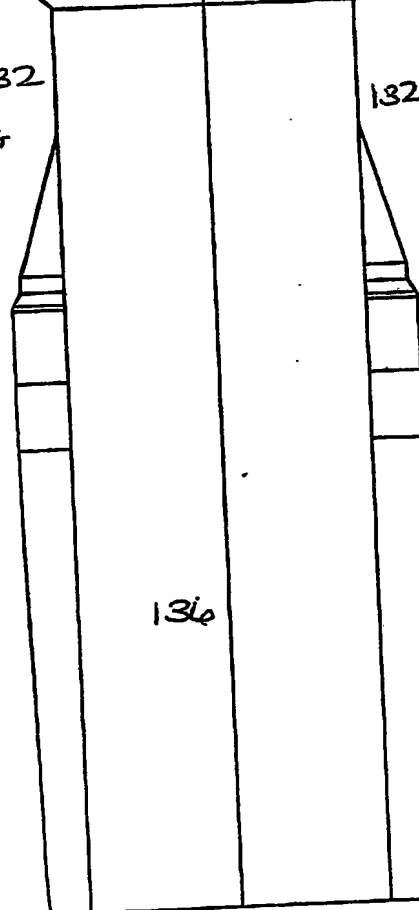


12

18

132

132



136

FIGURE 5(a)

FIGURE 5(c)

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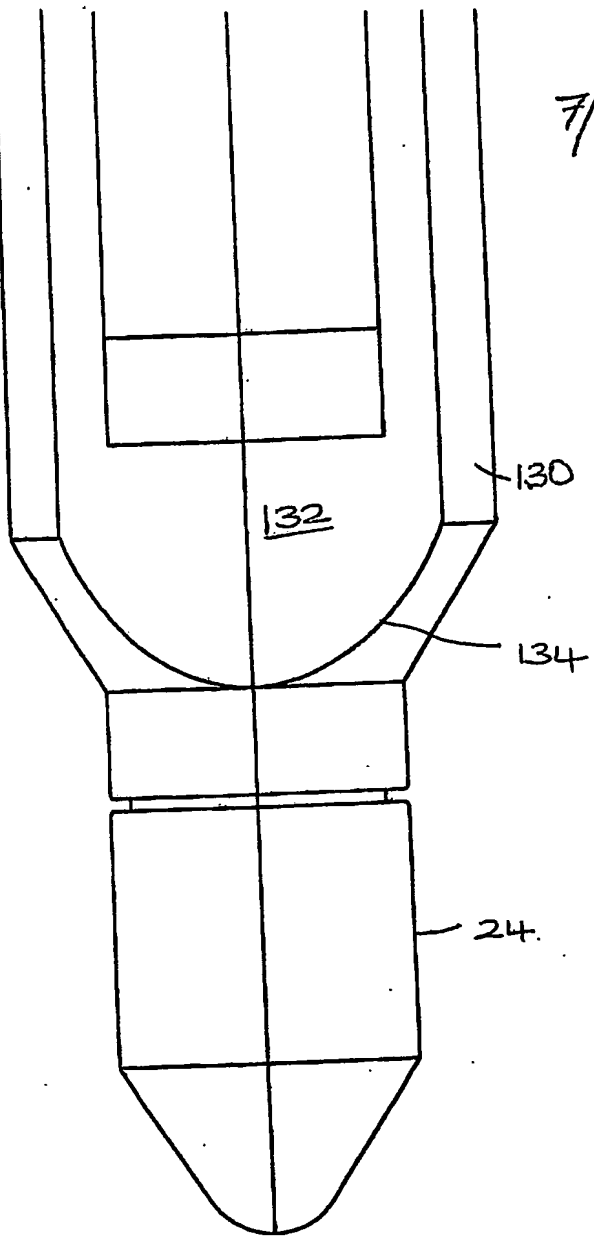


FIGURE 5(b)

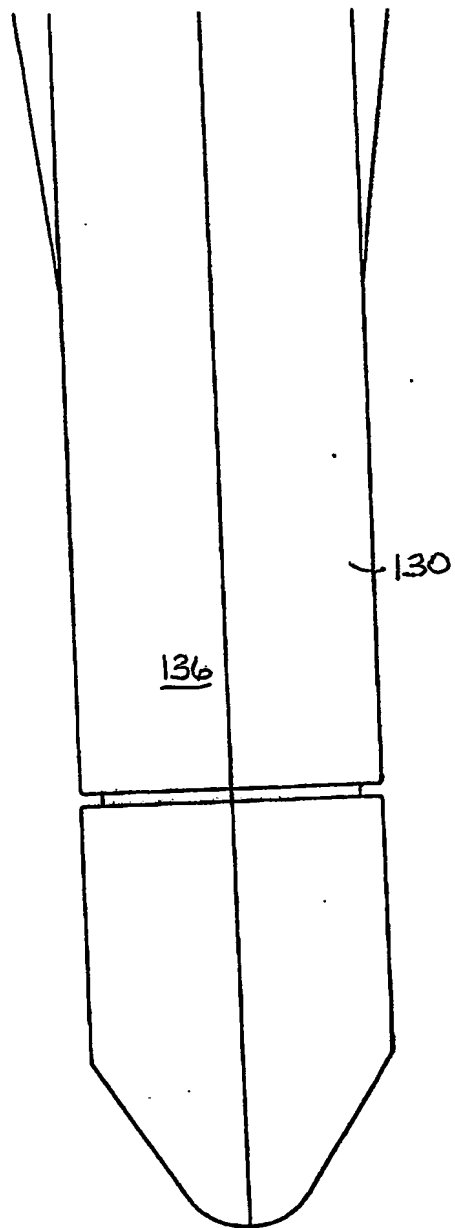
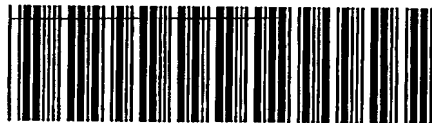


FIGURE 5(d)

PCT/GB2004/004890



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